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(54) Visual axis detection

(57) In order to determine the direction of the gaze of the user of an automatic focusing camera, the user's eyeball is illuminated by LEDs 4a, 4b. The eyeball and resultant reflections are viewed by CCD array 9 acting as an image sensor. In order to overcome problems arising from ambient light, during a first accumulation period in which the LEDs 4a, 4b are illuminated the output of array 9 is stored in RAM 21; during a second period, the LEDs 4a, 4b are not illuminated, and the resultant signal is subtracted from the stored signal; this difference signal is then used to determine the user's direction of gaze; a suitable autofocus sensor can then be selected.

FIG. 1

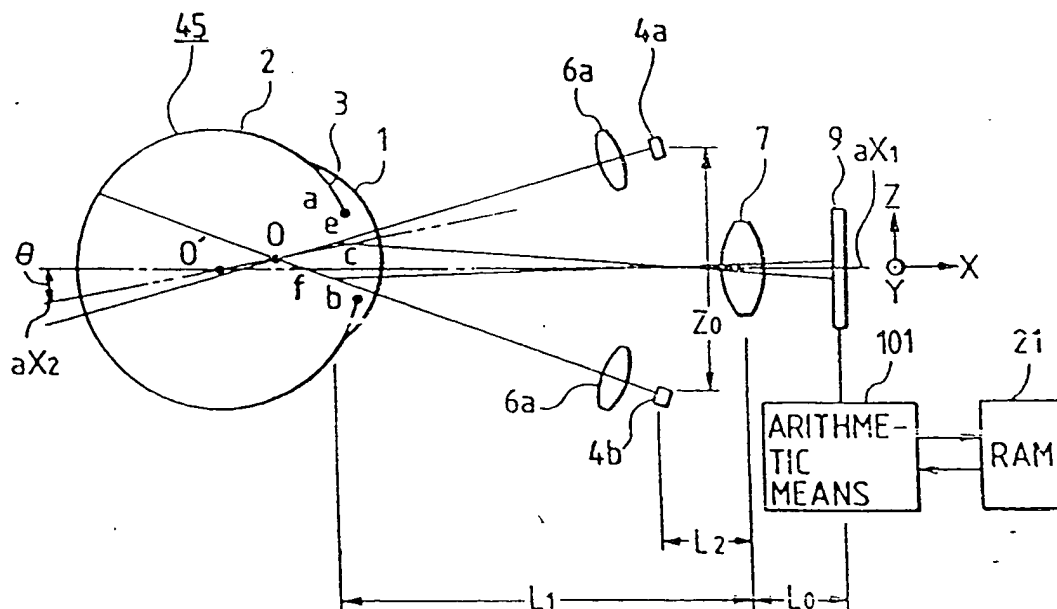




FIG. 2

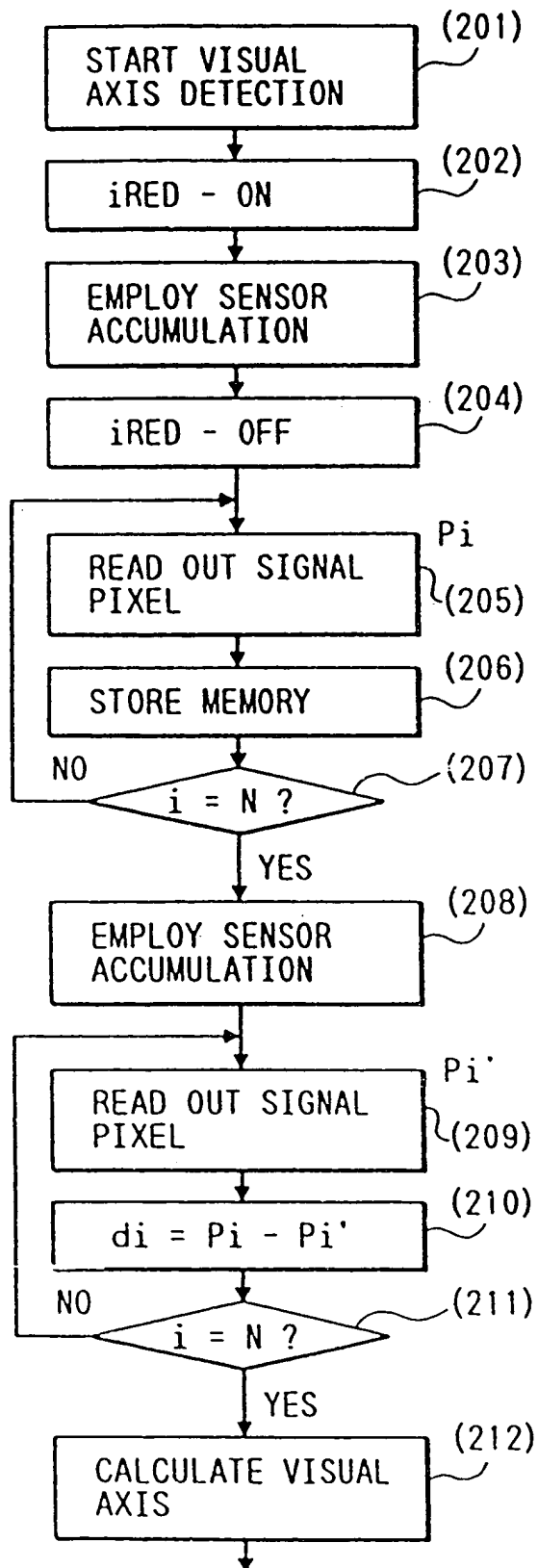


FIG. 3

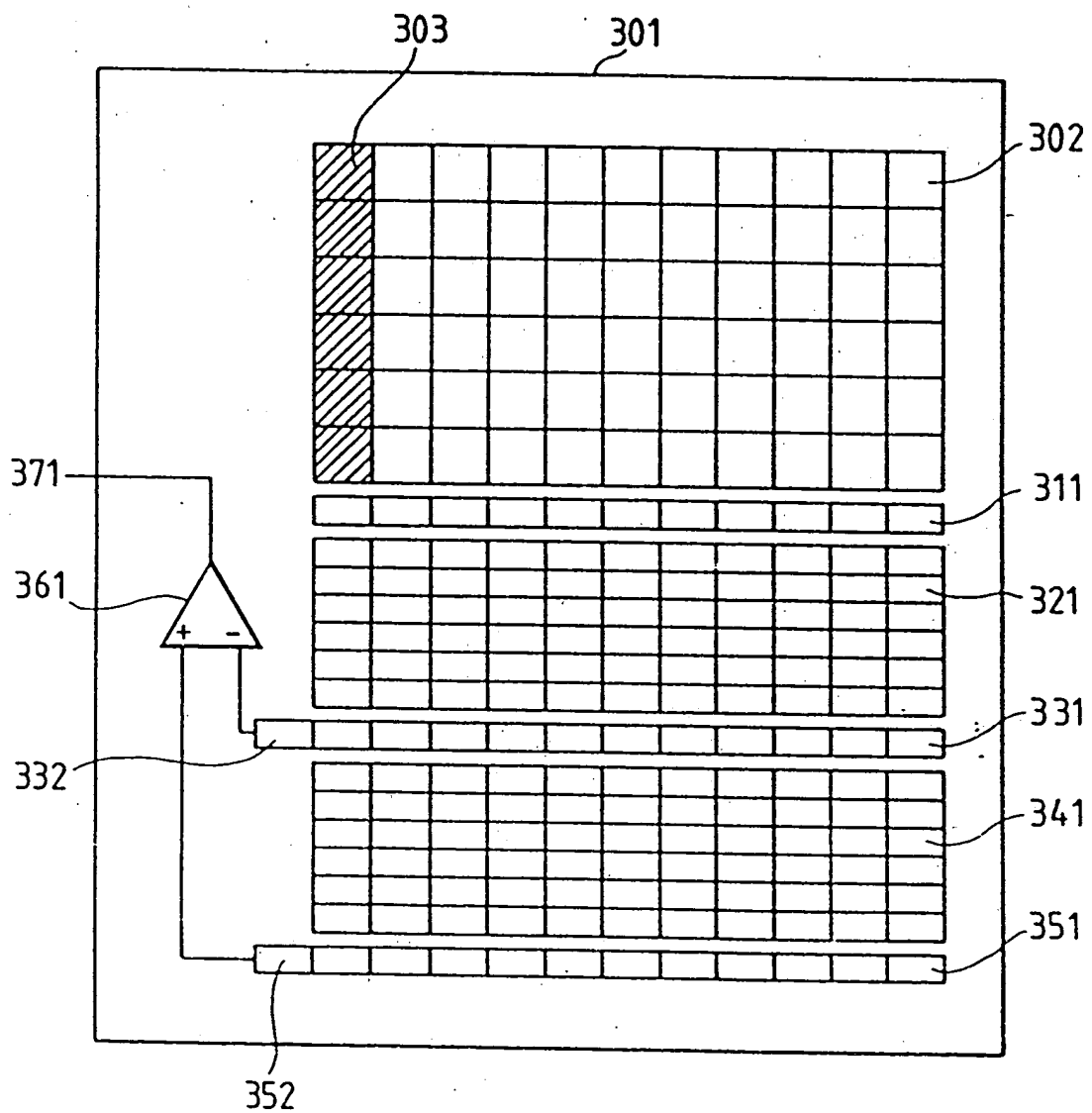


FIG. 4

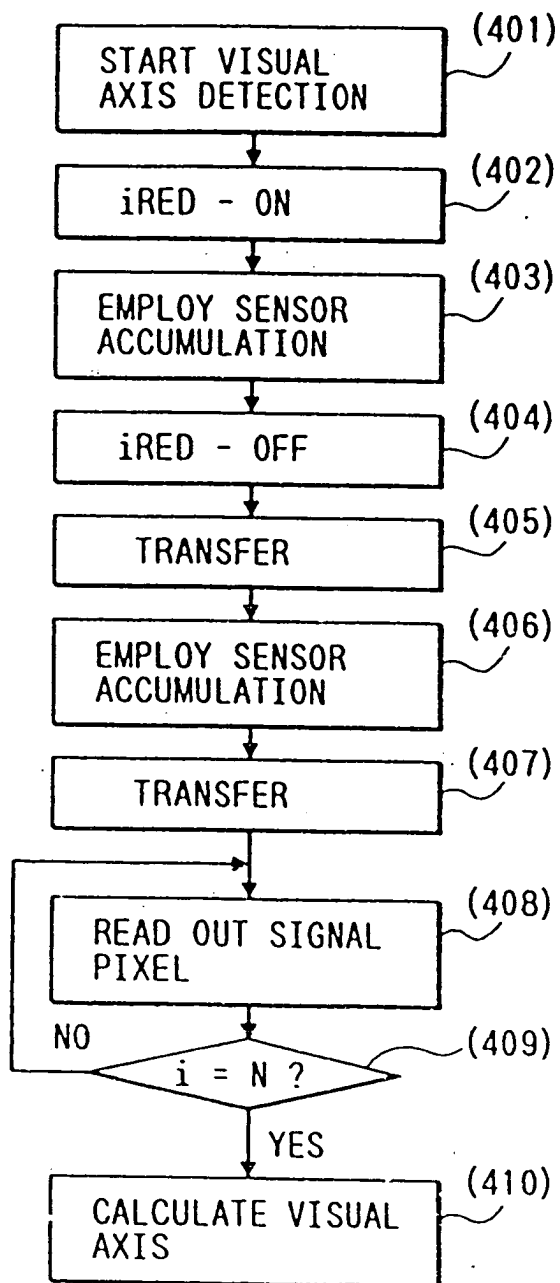


FIG. 5 PRIOR ART

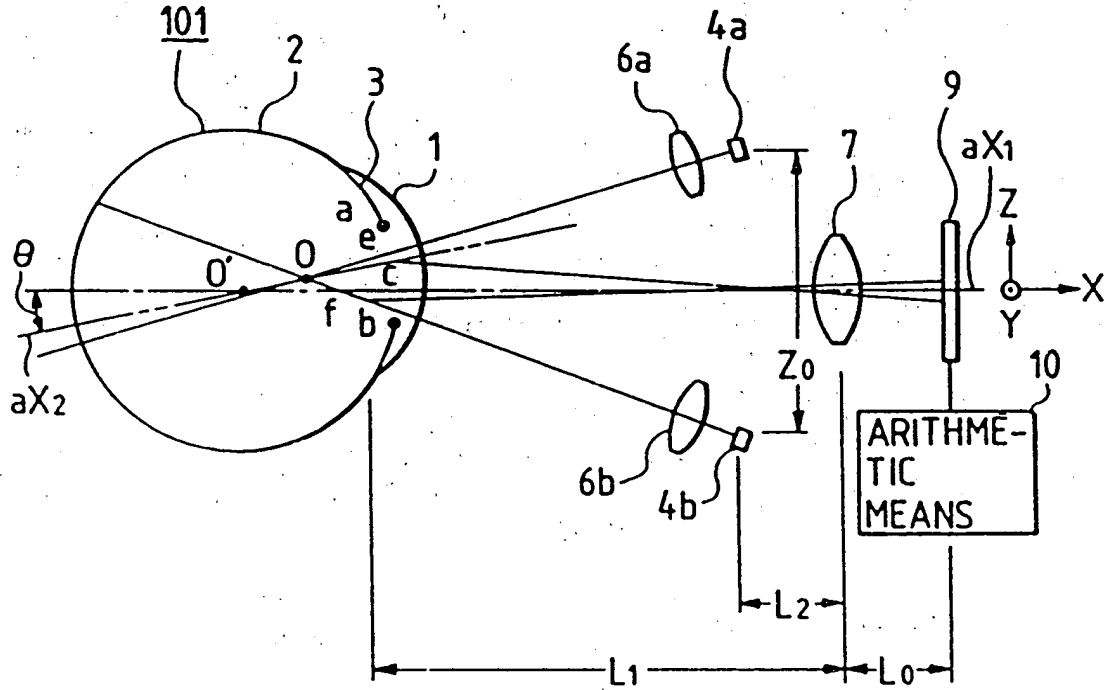


FIG. 6

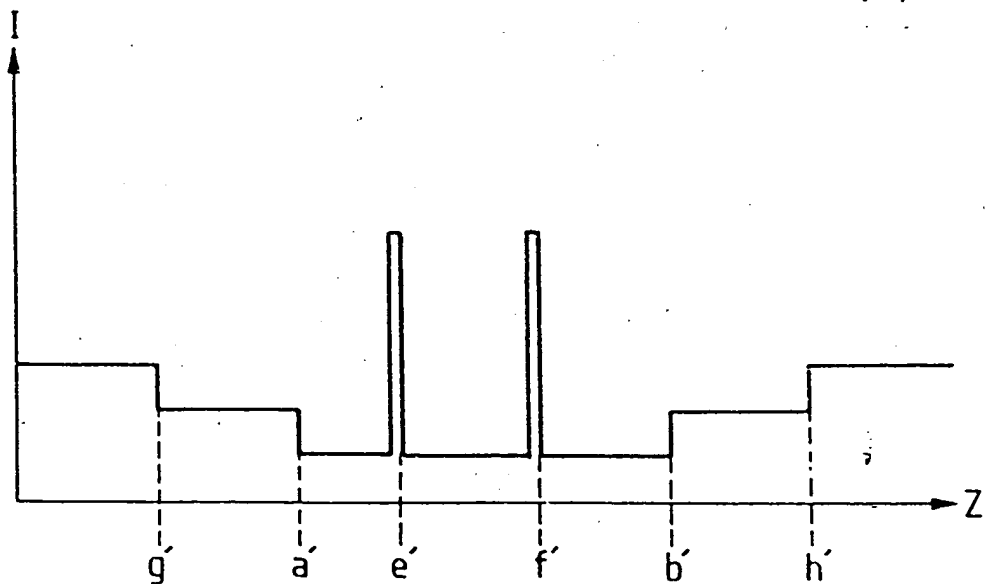


FIG. 7

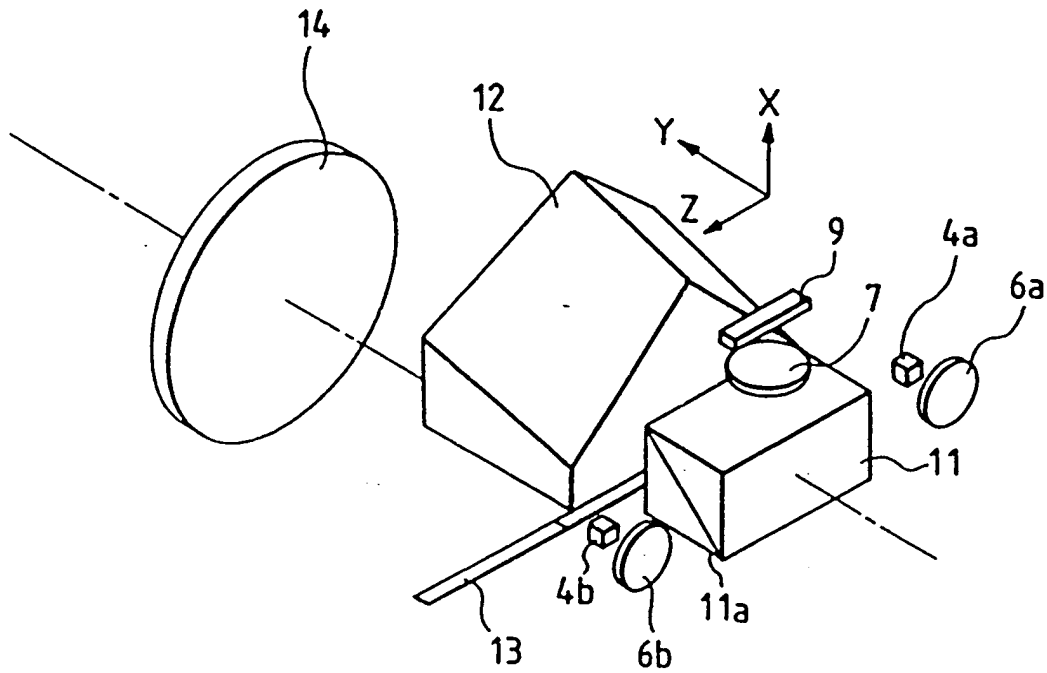


FIG. 8

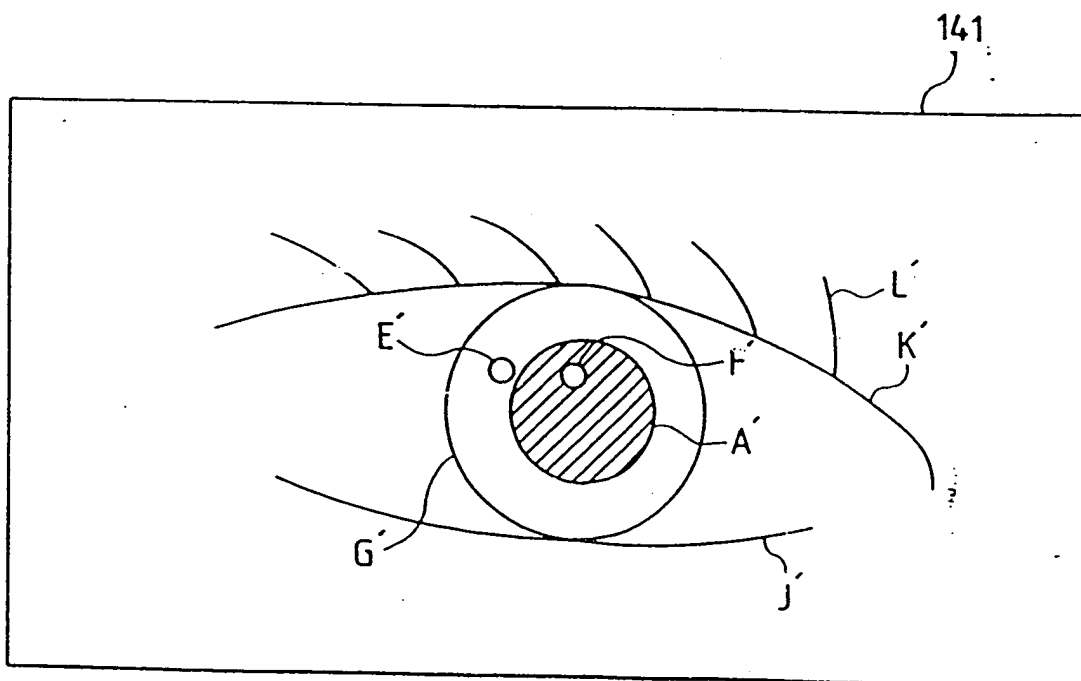
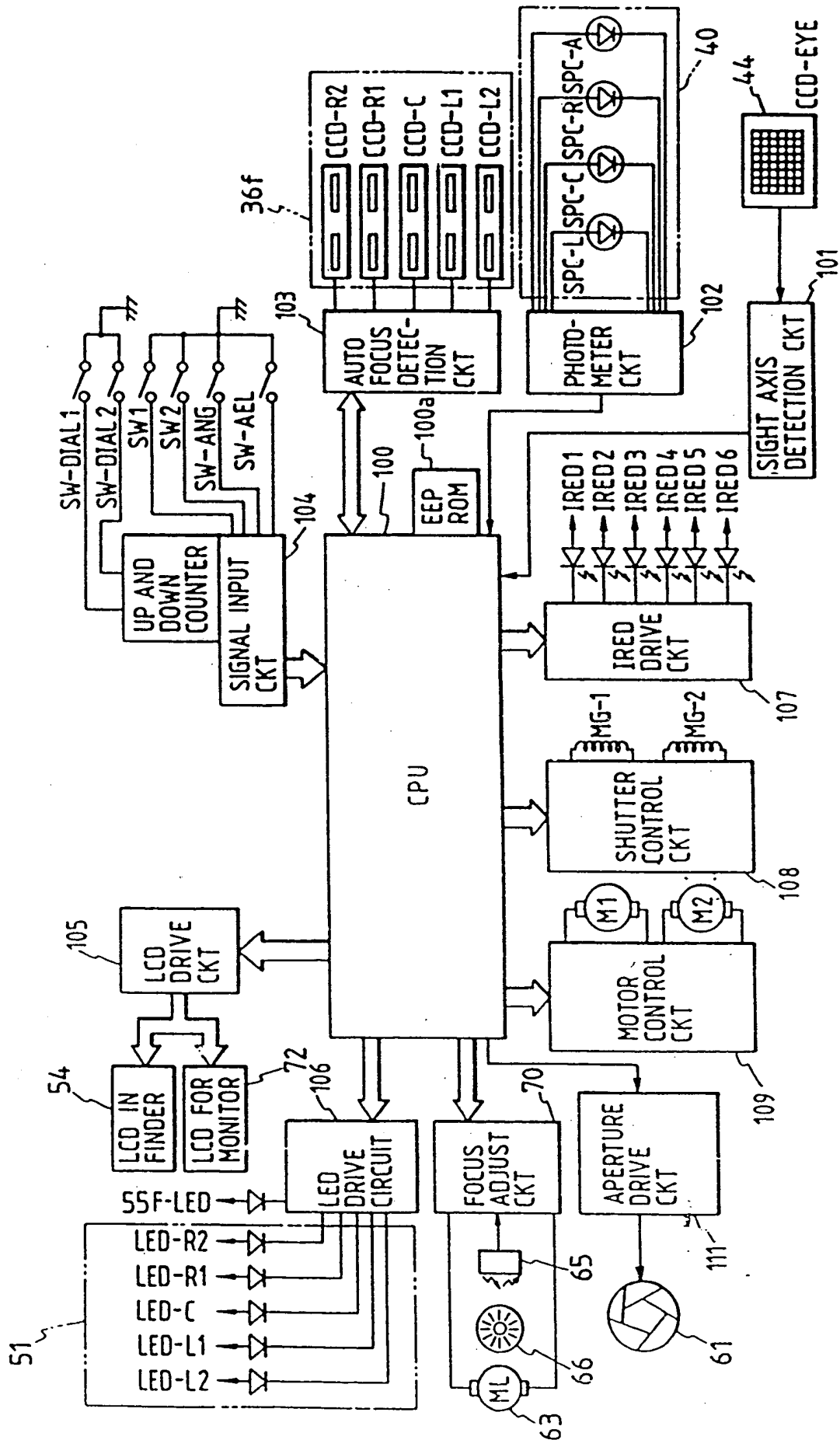






FIG. 10



## 1 VISUAL AXIS DETECTION APPARATUS

BACKGROUND OF THE INVENTIONField of the Invention

5 The present invention relates to a visual axis detection apparatus, and especially to a visual axis detection apparatus which detects an axis in an observation point direction of a viewer (photographer) or a so-called visual axis when the viewer observes  
10 an observation plane (imaging plate) on which an object image is formed by a photographing system in an optical system such as a camera, by utilizing a reflected image (eyeball image) formed when an eyeball of the viewer is illuminated with an infrared ray.

15 Related Background Art

Various visual axis detection apparatuses for detecting the visual axis to detect a position on a view plane which the viewer (examined person) views have been proposed.

20 For example, in Japanese Laid-Open Patent Application No. 2-264632, an infrared light beam from a light source is projected to an anterior eye in an eye to be examined and an axis of vision (observation point) is determined by utilizing a cornea reflected  
25 image on the basis of a reflected light from a cornea and a focus-imaging point on a pupil.

In a camera disclosed in Japanese Laid-Open

1 Patent Application No. 61-61135, a direction of  
metering by a focus detection apparatus is mechanically  
controlled on the basis of an output signal from a  
visual axis detection means to adjust a focal point  
5 state of a photographing system.

Fig. 5 is a schematic view of a visual axis  
detection apparatus proposed in Japanese Laid-Open  
Patent Application No. 2-264632, Fig. 6 is an explana-  
tion view for an output signal from one line of an  
10 image sensor of Fig. 5, and Fig. 7 is a perspective  
view of a portion of a finder system when the visual  
axis detection apparatus of Fig. 5 is applied to a  
single eye reflex camera.

Numeral 101 denotes an eyeball of an examined  
15 person (observer), numeral 1 denotes a cornea of the  
eyeball of the examined one, numeral 2 denotes a  
sclera, and numeral 3 denotes an iris. O' denotes  
a center of rotation of the eyeball 101, O denotes  
a center of curvature of the cornea 1, a and b denote  
20 ends of the iris 3, and e and f denote positions where  
cornea reflected images are formed owing to light  
sources 4a and 4b to be described hereinafter. Numeral  
4a and 4b denote light sources which may be light  
emitting diodes or the like for emitting infrared rays  
25 which are unpleasant for the examined one. The light  
source 4a (4b) is arranged closer to a projection lens  
6a (6b) than to a focal plane of the projection lens

1 6a (6b). The projection lenses 6a and 6b are applied  
for widely illuminating the cornea 1 defining a light  
beam from the light sources 4a and 4b as diverged light  
beam.

5 The light source 4a lies on an optical axis  
of the projection lens 6a and the light source 4b lies  
on an optical axis of the projection lens 6b, and they  
are arranged symmetrically along a z-axis direction  
with respect to an optical axis  $ax_1$ .

10 Numeral 7 denotes a light receiving lens which  
forms the cornea reflected images e and f formed near  
the cornea 1 and the ends a and b of the iris 3 on  
an image sensor plane 9. Numeral 10 denotes an  
arithmetic means which calculates the visual axis of  
15 the examined one by using the output signal from the  
image sensor 9.  $ax_1$  denotes an optical axis of the  
light receiving lens 7 and it matching to an X axis  
in Fig. 5.  $ax_2$  denotes an optical axis of the eyeball  
which makes an angle  $\theta$  to the X axis.

20 In this example, the infrared ray emitted from  
the light source 4a (4b) passes through the projection  
lens 6a (6b) and thereafter widely illuminates the  
cornea 1 of the eyeball 101 with diverging state. The  
infrared ray which passes through the cornea 1 illumi-  
25 nates the iris 3.

The cornea reflected images e and f based on  
the light beam reflected by the surface of the cornea

1 of the infrared rays for illuminating the eyeball  
are reformed at points  $e'$  and  $f'$  on the image sensor  
9 through the light receiving lens 7. In Figs. 5 and  
6,  $e'$  and  $f'$  denote projection images of the cornea  
5 reflected image (virtual images)  $e$  and  $f$  formed by  
a set of light sources 4a and 4b. Centers of the  
projection images  $e'$  and  $f'$  substantially match to  
the projection point on the image sensor 9 of the cornea  
reflected image formed when the illumination means  
10 is arranged on the optical axis  $ax_1$ .

The infrared ray which is diffusion-reflected  
by the surface of the iris 3 is directed to the image  
sensor 9 through the light receiving lens 7 to form  
the iris image.

15 On the other hand, the infrared ray transmitted  
through the pupil of the eyeball illuminates a retina  
has the wavelength of the infrared range and the  
illuminated area is an area of a low view cell density  
which is apart from a center area, so that the examined  
20 one cannot recognize the light sources 4a and 4b.

An ordinate in Fig. 6 represents an output  
I along the z-axis direction of the image sensor 9.  
Since most of the infrared ray transmitted through  
the pupil are not reflected back, there is no difference  
25 of the output at the boundary between the pupil and  
the iris 3. As a result, the iris images  $a'$  and  $b'$   
at the ends of the iris can be detected.

1        When an area sensor having a two-dimensional  
photo-sensor array is used as the image sensor 9 of  
Fig. 6, two-dimensional light distribution information  
of the reflected image (eyeball image) is obtained  
5 from the front eye as shown in Fig. 8.

In Fig. 8, numeral 141 denotes a light receiving  
area of the image sensors, E' and F' denote cornea  
reflected images of the light sources 4a and 4b, A'  
denotes a boundary between the iris and the pupil,  
10 and G' denotes a boundary between the sclera 2 and  
the cornea 1. Since the reflectivities of the sclera  
1 and the iris 3 are not substantially different from  
each other in the infrared range, the boundary G' can  
not be clearly discriminated by a naked eye. J' denotes  
15 an image of a lower eyelid, K' denotes an image of  
an upper eyelid and L' denotes an image of eyelashes.

In order to detect the direction of the visual  
axis from the eyeball image of the front eye, it has  
been known to calculate a relative relation between  
20 the cornea reflected images E' and F' (or an interme-  
diate image of E' and F') and the position of the center  
of pupil. Various methods for determining the center  
of pupil have been known. For example, an output of  
one particular line of the image sensor is sampled  
25 to calculate a center point of the pupil edge positions  
a' and b' of Fig. 6. Alternatively, the output  
information of the area sensor may be used to sample

1 a number of pupil edge points and thereafter determine  
the center point by a least square approximation.

An optical equipment having a finder system  
such as a still camera or a video camera is frequently  
5 used in out-of-door. When such an optical equipment  
is used in out-of-door, the eyeball of the photographer  
is illuminated by an external ray. Thus, an image  
forming light beam received by the image sensor 9  
includes not only the image of the front eye illuminated  
10 with the light sources 4a and 4b but also a complex  
image affected by disturbance by the external ray.

The most problem external ray is a direct light  
incident on the front eye from the sun. An energy  
of the sunlight is very strong and includes a plenty  
15 of the same spectrum components as those of the  
spectrums emitted by the light sources 4a and 4b.  
Accordingly, it is difficult to fully eliminate the  
external ray by spectrum means such as a visible ray  
cut filter.

20 When the front eye is illuminated by the  
sunlight, a variety of disturbances are generated in  
the image. When the amount of external ray is largely  
illuminated, the external ray component is stronger  
than infrared component. As a result, a pattern  
25 (eyeball image) cannot be substantially discriminated.  
When the external ray exists, a brightness in the pupil  
which should be at a lowest brightness level of

1 luminescence (between a' and b' in Fig. 6) becomes higher  
or declined so that the detection of the pupil edges  
and hence the decision of the center of the pupil  
cannot be correctly determined.

5           When the neighborhood of the boundary of the  
sclera and the iris is strongly illuminated, a obscure  
edge which inherently seems unclear rises to the surface  
or becomes declined therein, so that the pupil edges  
are misdetected. When the eyelashes grow downward,  
10 they are illuminated by the external ray, so that they  
may be misdetected as the pupil edge. Since the  
eyelashes extend out of the face in contrast to the  
eyeball, they are easily subject to the illumination  
by the external ray.

15           Such a misdetection occurs not only for the  
pupil edge but also for the cornea reflected images  
e and f of the light sources 4a and 4b. When the ends  
of the eyelashes are directly illuminated by the  
sunlight, they become strong brilliant points, which  
20 are misdetected as the cornea reflected images. When  
eyeglasses are put, dusts deposited on the eyeglasses  
may be highlighted.

          Besides the sunlight, a down light having high  
luminescence and various artificial light sources are  
25 also utilized as the external ray. When eyeglasses  
are put, a distance between the eyepiece portion in  
the finder system and the eyeball generally becomes



1 apart, so that the external ray easily enters into  
the eye. Further, the reflection coming from the lens  
surfaces of the eyeglasses is adversely affected.

When the visual axis is to be detected by using  
5 the image signal from the image sensor, an accumulation-  
type image sensor is frequently used in view of a  
requirement for the sensitivity. As a result, there  
has been a problem that a DC noise elimination by an  
AC coupling or a period detection system which is  
10 usually used in a single sensor cell cannot be used.

The present invention is concerned with  
providing a visual axis detection apparatus for detecting  
15 an eyeball image by using accumulation-type image pickup  
means which reduces an affect by a noise due to an  
external ray and detects the visual axis of the eyeball  
of the photographer (the examined person) who looks into  
a finder, by properly setting an accumulation method  
20 of the eyeball image (image information) by the image  
pickup means and a processing method of the image  
information based on the eyeball image from the image  
pickup means.

In the visual axis detection apparatus of the  
25 present invention, the eyeball of the examined person  
is illuminated by a light beam coming from illumination  
means, an eyeball image based on a reflected light

1 from the eyeball is formed on a surface in accumulation-  
type image pickup means, an image signal from the image  
pickup means is stored in memory means, and a visual  
axis of the examined person is calculated by utilizing  
5 the image signal stored in the memory means. The image  
pickup means has first and second accumulation periods  
and the memory means stores the image signal of the  
eyeball generated in one of the two accumulation periods  
and the illumination means emits a light in one of  
10 the two accumulation periods. A difference signal  
between the image signal from the image pickup means  
generated in the first accumulation period and the  
image signal generated in the second accumulation period  
is determined by differential signal generation means  
15 and the visual axis of the examined person is detected  
based on the signal from the differential signal  
generation means.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 Fig. 1 shows a main schematic view of the  
embodiment 1;

Fig. 2 shows a flowchart of the embodiment 1;

Fig. 3 shows a main schematic view of an image  
sensor of the embodiment 2;

25 Fig. 4 shows a flowchart of the embodiment 2;

Fig. 5 shows a main schematic view of a  
conventional visual axis detection apparatus;

1           Fig. 6 shows an explanation view of output  
signal from the image sensor in Fig. 5;

          Fig. 7 shows a main schematic view when the  
visual axis detection apparatus is applied to a single  
5   reflex camera;

          Fig. 8 shows an explanation view of an eyeball  
image formed on an area sensor;

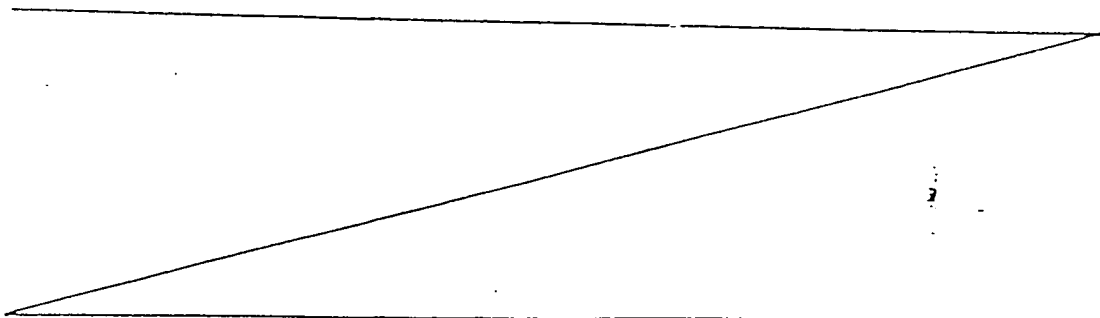
          Fig. 9 shows a view when the visual detection  
apparatus is mounted into a single reflex camera; and

10           Fig. 10 shows a block diagram for explaining  
how the apparatus in Fig. 9 is controlled.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

          Fig. 1 shows a schematic diagram of Embodiment  
15   1 of the present invention and Fig. 2 shows a flow  
chart for explaining the visual axis detection in the  
Embodiment 1.

          In the present embodiment, in contrast to the  
conventional visual detection apparatus of Fig. 5,  
20   a photo-electrically converted signal from the image  
sensor 9 which functions as the accumulation-type image



1 pickup means is processed by arithmetic means 101,  
 and a RAM (memory) 21 for storing the data from the  
 arithmetic means 101 is further provided. Specifically,  
 the visual axis operation method is improved in the  
 5 arithmetic means 101 by using the data stored in the  
 RAM 21 to eliminate the adverse affect by the external  
 ray.

The elements of the present embodiment are  
 now explained in sequence although it may be partially  
 10 duplicate to the description for Fig. 5.

In Fig. 1, numeral 45 denotes an eyeball of  
 an examined one (viewer), numeral 1 denotes a cornea  
 of the eyeball of the examined one, numeral 2 denotes  
 a sclera and numeral 3 denotes an iris. O' denotes  
 15 a center of rotation of the eyeball 101, O denotes  
 a center of curvature of the cornea 1, a and b denote  
 ends of the iris 3, and e and f denote positions where  
 cornea reflected images are generated by light sources  
 4a and 4b to be described hereinafter. Numerals 4a  
 20 and 4b denote light sources which may be light emitting  
 diodes for emitting infrared rays which are unpleasant  
 by the examined one. The light source 4a (4b) is  
 arranged closer to a projection lens 6a (6b) than to  
 a focal plane of the projection lens 6a (6b). The  
 25 projection lenses 6a and 6b convert the light beams  
 from the light sources 4a and 4b to diverging lights  
 to widely illuminate on a surface of the cornea 1.

1           The light source 4a lies on an optical axis  
of the projection lens 6a while the light source 4b  
lies on an optical axis of the projection lens 6b and  
they are arranged symmetrically along a z-axis relative  
5 to an optical axis  $ax_1$ . The light sources 4a and 4b  
and the projection lenses 6a and 6b form the illumination  
means.

          Numeral 7 denotes a light receiving lens which  
focuses the cornea reflected images e and f formed  
10 in the vicinity of the cornea 1 and the ends a and  
b of the iris 3 onto the image sensor 9. The light  
receiving lens 7 and the image sensor 9 form one of the  
light receiving means which converts the light  
from the eye into an electrical signal.

15           Numeral 101 denotes an arithmetic means which  
calculates the visual axis of the examined person by  
using the output signal from the image sensor 9, as  
will be described hereinafter. The basic detection  
method therefor is described in Japanese Laid-Open  
20 Patent Application No. 4-447127. Numeral 11 denotes  
a RAM which functions as the memory means which stores  
data calculated by the arithmetic means 101.  $ax_1$   
denotes an optical axis of the light receiving lens  
7, which matches with an X-axis.  $ax_2$  denotes an optical  
25 axis of the eyeball which makes angle  $\theta$  to the X-axis.

          In the present embodiment, the infrared ray  
emitted from the light source 4a (4b) passes through

1 the projection lens 6a (6b) and thereafter diverges  
to widely illuminate the cornea 1 of the eyeball 45.  
The infrared ray transmitted through the cornea 1  
illuminates the iris 3.

5 The cornea reflected images e and f based on  
the light beam reflected by the surface of the cornea  
1, of the infrared rays illuminating the eyeball are  
reimaged onto the points e' and f' on the image sensor  
9 through the light receiving lens 7. In Figs. 1 and  
10 6, e' and f' denote projection images of the cornea  
reflected images (virtual images) e and f generated  
by the set of light sources 4a and 4b. A mid-point  
of the projection images e' and f' substantially matches  
to the projection position of the cornea reflected  
15 image on the image sensor 9, which is generated when  
the illumination means is arranged on the optical axis  
ax<sub>2</sub>.

The infrared ray which is diffusion-reflected  
by the surface of the iris 3 is introduced into the  
20 image sensor 9 through the light receiving lens 7 to  
form the iris image.

On the other hand, the infrared ray transmitted  
through the pupil of the eyeball illuminates the retina  
and is absorbed thereby. However since the illuminated  
25 area has a low density of viewing cells which is apart  
from the center, the examined one cannot discriminate  
the light sources 4a and 4b.

1           In Fig. 6, an ordinate represents an output  
 I in the z-axis of the image sensor 9. Since most  
 of the infrared rays transmitted through the pupil  
 are not reflected back, there arises a difference in  
 5 the outputs at the boundary between the pupil and the  
 iris 3 and the iris images a' and b' of the iris edges  
 are detected.

In the present embodiment, the arithmetic means  
 101 respectively detects coordinates (Za', Zb' and  
 10 Ze', Zf') of peculiar points (a', b' and e', f') on  
 the eyeball on the image sensor 9 based on a flow chart  
 of Fig. 2, and calculates a rotation angle  $\theta$  of the  
 eyeball in accordance with a formula:

$$\beta \cdot \overline{OC} \cdot \sin \theta \approx (Za' + Zb')/2 - (Ze' + Zf')/2$$

15 where  $\beta$  is a magnification factor of the light receiving  
 optical system ( $\approx L_0/L_1$ ).

A vision angle of the eyeball is determined  
 from the rotation angle  $\theta$  to determine of the subject.

In the line of vision detector of the present  
 20 invention, a distance  $L_1$  between the position at which  
 the cornea reflected image is generated and the light  
 receiving lens 7 satisfies a relation of:

$$(L_1 |Ze' - Zf'|)/L_0 Z_0 \approx \overline{OC}/(L_1 - L_2 + \overline{OC})$$

where  $Z_0$  is a spacing in the z-direction of the set  
 25 of light sources 4a (4b), and  $L_2$  is a spacing in the  
 x direction between the light source 4a (4b) and the  
 light receiving lens 7.

1           Thus, even if the distance between the line  
of vision detector and the eyeball changes, the distance  
 $L_1$  may be calculated from the spacing  $|Ze'-Zf'|$  of  
the two cornea reflected images.

5           An operation of the visual axis detection  
apparatus is now explained with reference to the flow  
chart of Fig. 2.

          In a step 201, the detection operation of the  
visual axis starts. In a step 202, the light sources  
10 4a and 4b are turned on and at the substantial same time,  
the process proceeds to a step 203 to start the first  
accumulation operation of the image sensor 9. The  
accumulation by the image sensor 9 may be controlled  
by comparing a real time accumulation amount motor  
15 signal with a predetermined reference, or by time  
control by hardware or software timer.

          The process proceeds to a step 204 at the  
substantial end time of the first accumulation of the  
image sensor to turn off the light sources 4a and 4b.  
20 The photo-electric conversion signals of the image  
sensor 9 are sequentially read through a loop of steps  
205-207 and the A/D converted electrical signals  $P_i$   
of the cells are stored in the memory (RAM) 21. Where  
the image sensor 9 itself does not have a memory func-  
25 tion, the image sensor 9 may senses the light and  
error-move during reading the signals. Accordingly,  
the loop is designed to be completed in a sufficiently



1 short time in comparison with the accumulation time.

Where the image sensor 9 includes an analog  
memory function, the signal charges may be temporarily  
shifted to the non-photosensitive memory and sequen-  
5 tially read into digital system at a low speed. The  
memory function of the present embodiment may be  
implemented as a CCD channel or a capacitor array.

When the reading and storing of all of the  
required pixels are completed, the process proceeds -  
10 to a step 208 to conduct the second accumulation  
operation. The accumulation time of the second  
accumulation is substantially same as the accumulation  
time of the first accumulation done in the step 203.

In the second accumulation operation, the light  
15 sources 4a and 4b are not turned on and the front eye  
image is sampled by only the external ray illumination  
to cancel the external ray components. In the present  
embodiment, the accumulation time may be reduced to  
one half and the read gain may be doubled in order  
20 to reduce the accumulation time while keeping the  
apparent signal quantity.

When the second accumulation operation is  
finished, the photoelectric conversion signals of the  
image sensor are sequentially read through a loop of  
25 steps 209-211.

Then the arithmetic means 10 reads the signals  
Pi of the same pixels produced in the first accumulation,

1 calculates differences  $d_i$  between the signals  $P_i$  and  
the current signals  $P_i'$  and restores the result in  
the memory 21.

In the present embodiment, the arithmetic means  
5 101 also includes a function of differential signal  
generation means for determining the differential signal  
 $P_i'$ . This operation is carried out for all the pixels  
so that the memory 21 has an image signal based on  
the eyeball image which substantially eliminates the  
10 contribution of the external ray due to the sunlight  
or the like. In the present embodiment, the direction  
of the visual axis is calculated in a step 212 based  
on the above image signal so that the malfunction is  
prevented and the highly accurate detection of the  
15 visual axis is attained.

Fig. 3 shows a schematic view of an image sensor  
(a sensor chip) 301 in Embodiment 2 of the present  
invention, and Fig. 4 shows a flow chart of the opera-  
tion of the present embodiment. Other elements of  
20 the present embodiments are substantially identical  
to those of the Embodiment 1.

In Fig. 3, numeral 301 denotes a sensor chip  
having a well-known self-scanning system and a power  
supply and the like, and it is shown as a functional  
25 block in Fig. 3 for simplification.

The sensor chip 301 is provided at the position  
of the image sensor 9 in Fig. 1. Numeral 302 denotes

1 a photo-sensing block which is a CCD sensor having  
M x N areas. Fig. 3 shows a frame-transfer-type system  
which shares the photo-sensing unit with a transfer  
unit although the same function may be attained by  
5 an interline-type system. A masked column 303 is  
provided at a left end of the photo-sensitive area.  
It is a monitor pixel to detect a dark signal level.  
A transfer buffer 311, a first memory 321, a transfer  
buffer/horizontal read register 331, a second memory  
10 unit 341, a transfer buffer/horizontal read register  
351, and a differential amplifier 361 are provided  
in sequence. The elements other than the photo-sensitive  
area are fully shielded from the light by an aluminum  
film or the like.

15 An operation of the present embodiment is now  
explained with reference to a flow chart of Fig. 4.

In a step 401, the visual axis detection  
operation starts. In a step 402, the light sources  
4a and 4b are turned on. At the substantially same  
20 time, the first accumulation operation of the image  
sensor 301 is started in a step 403, and after employing  
the accumulation to a predetermined monitor level or  
after a predetermined time, the accumulation is  
terminated.

25 In a step 404, the light sources 4a and 4b  
are turned off, and in a step 405, the transfer  
operation is conducted. In the transfer operation,

1 the signal charges accumulated in the photo-sensing  
unit 302 of the image sensor 301 are transferred to  
the memory unit 321 through the transfer buffer 311.

The transfer method is well-known. In the  
5 illustrated frame-transfer-type system, the signal  
charges of the pixels are transferred downward one  
line per one clock. The entire image is transferred  
to the memory unit 321 by (N+1) clocks including those  
for the buffer. It is necessary that the time required  
10 for the transfer is sufficiently shorter than the  
accumulation time. In the present embodiment, the  
transfer rate of the CCD channel is determined by the  
hardware and it is sufficiently high, so that any problem  
does not arise.

15 When the transfer is over, the process proceeds  
to a step 406 to conduct the second accumulation  
operation. Since the charges of the photo-sensing  
unit are evacuated by the previous transfer operation,  
a reset operation is not necessary but it may be  
20 conducted prior to the second accumulation if the  
circuit is designed to conduct the reset operation.

In the second accumulation, the light sources  
4a and 4b are not turned on and the signal charges  
by only the external ray are accumulated. After  
25 completing the accumulation, the process proceeds to  
a step 407 to conduct the transfer..

In the transfer operation, the signal charges

1 accumulated in the photo-sensing unit 302 are transfer-  
 red to the memory unit 321 and at the same time the  
 signal charges stored in the memory 321 by the first  
 accumulation are transferred to another memory unit  
 5 341. Since they are simultaneously and parallelly  
 proceeded, the signal charges by the two accumulations  
 are not mixed and the transfers are completed by  $(N+1)$   
 clocks. Finally, the signal charges by the first  
 accumulation are stored in the memory 341 and the signal  
 10 charges by the second accumulation are stored in the  
 memory 321.

In the next sequence, the signal is read  
 outwardly through a loop of steps 408-409. This  
 sequence may be lower at speed than the transfer in  
 15 the sensor chip owing to an external radial circuit  
 but the signal may be read without regard to the sensing  
 by the sensor because the signal charges have been  
 transferred to the light-shielded memory unit.

The signal charges stored in the memory units  
 20 (321 and 341) are sequentially transferred, pixel by  
 pixel, to the charge-voltage converters 332 and 352  
 by the function of the horizontal line read registers  
 331 and 351, and the signal voltages are applied to  
 the input terminals of the differential amplifier 361.  
 25 Since the both horizontal registers 331 and 351 are  
 operated by one clock simultaneously, the signals of  
 the same pixel of the photo-sensing unit 302 produced

1 in the first and second accumulations are simultaneously  
applied to the positive and negative inputs of the  
differential amplifier 361. As a result, the image  
signal which the external ray components is subtracted  
5 therefrom appears at the output terminal 371. When  
it is done for all pixels, the process proceeds to  
a step 410 to calculate the visual axis. In the  
present embodiment, the affection caused by the  
external ray is eliminated in such a manner to attain  
10 a highly reliable signal.

In the present embodiment, a capacitor array  
may be also used to eliminate the external ray in the  
sensor chip. An image sensor which temporarily stores  
the photo-excited image signal charges in the capacitor  
15 array through a current amplifier element such as a  
transistor and thereafter sequentially read them out  
has been known, and hence the elimination of the  
external ray which is functionally equivalent to the  
CCD arrangement described above may be attained.

20 Only one set of the memory unit may be provided  
for the first accumulation signal and the second  
accumulation signal may be subtracted on the chip and  
the result is output. Alternatively, it may be  
re-stored in the memory. The significance of the  
25 present invention is not limited by the specific  
details of the implementation.

Fig. 9 shows a schematic diagram of an

1 embodiment in which the line of vision detector of  
the present invention is applied to a single reflex  
camera.

5 In Fig. 9, numeral 31 denotes a photographing  
lens which comprises two lenses for the sake of  
convenience although it actually comprises more lenses.  
Numeral 32 denotes a main mirror which is skewed into  
a photographing path or retracted therefrom depending  
on a view state of an object by a finder system and  
10 a photographing state of an object image. Numeral  
33 denotes a sub-mirror which reflects a light beam  
transmitted through the main mirror 32 to a focal point  
detection apparatus 39 at a bottom of a camera body  
to be described later.

15 Numeral 34 denotes a shutter and numeral 35  
denotes a photo-sensing member such as a silver salt  
film, CCD or MOS or the like solid state image pickup  
device, or an image pickup tube such as a videcon.

Numeral 36 denotes a focal point detection  
20 apparatus which comprises a field lens 36a arranged  
near a focusing plane, reflection mirrors 36b and 36c,  
a secondary image forming lens 36d, a diaphragm 36e  
and a line sensor 36f and the like including a plurality  
of CCD's.

25 The focal point detection apparatus 36 in the  
present embodiment uses a well-known phase difference  
system. Numeral 37 denotes an imaging plate arranged

1 on an anticipated focusing plane of the photographing  
lens 31, numeral 38 denotes a pentadaha prism for  
altering a finder optical path, and numerals 39 and  
40 denotes an image forming lens and a photometering  
5 sensor, respectively, for measuring an brightness of  
the object in the view field. The focusing lens 39  
is related in conjugate with the imaging plate 37 and  
the photometering sensor 40 through a reflection optical  
path in the pentadaha prism 38.

10 An eyepiece lens 41 having an optical splitter  
41a is arranged behind an exit plane of the pentadaha  
prism 38 and it is used for the observation of the  
imaging plate 37 by the eye 45 of the photographer.  
The optical splitter 41a comprises a dichroic mirror  
15 which transmits a visible ray and reflects an infrared  
ray.

Numeral 42 denotes a light receiving lens and  
numeral 44 denotes an image sensor having two-dimen-  
sionally arranged photo-electric element array such  
20 as CCD's as explained above, which is arranged in  
conjugate with the vicinity of the pupil of the eye  
45 of the photographer which is at a predetermined  
position with respect to the light receiving lens 42  
(corresponding to 9 in Fig. 1). Numeral 43 denotes  
25 an infrared ray emitting diode which functions as the  
light source (corresponding to 4 in Fig. 1).

Numeral 51 denotes a high intensity superimposing



1 LED which can be recognized even for a bright object.  
 The emitted light is reflected by the main mirror 32  
 through the projection lens 52 and vertically deflected  
 by a fine prism array 37a arranged at a display area  
 5 of the imaging plate 37 and reaches the eye 45 of the  
 photographer through the penta prism 38 and the eyepiece  
 lens 41.

The fine prism arrays 37a are formed in frame  
 shape at a plurality of points (metering points)  
 10 corresponding to the focus detection area of the imaging  
 plate 37, and they are illuminated by five corresponding  
 superimposing LED's 51 (which are defined as LED-L1,  
 LED-L2, LED-C, LED-R1 and LED-R2).

Numeral 53 denotes a view field mask which  
 15 forms a finder view field and numeral 54 denotes an  
 LCD in the finder for displaying photographing informa-  
 tion outside of the finder view field. It is illuminated  
 by an illumination LED (F-LED) 55.

The light transmitted through the LCD 54 is  
 20 introduced into the finder view field by a triangular  
 prism 56 and it is displayed outside of the finder  
 view field so that the photographer may recognize the  
 photographing information.

Numeral 61 denotes a diaphragm provided in  
 25 the photographing lens 31, numeral 64 denotes an  
 aperture driver including an aperture drive circuit  
 70 to be described later, numeral 63 denotes a lens

1 drive motor, numeral 64 denotes a lens drive member  
 including drive gears and the like, and numeral 65  
 denotes a photo-coupler which detects the rotation  
 of a pulse disk 66 coupled to the lens drive member  
 5 64 and transmits it to the lens focal point adjusting  
 circuit 70, which drives the lens drive motor based  
 on the information from the photo-coupler 65 and the  
 lens driving amount information from the camera to  
 drive the photographing lens 31 into an in-focus  
 10 position. Numeral 67 denotes a well-known mount contact  
 point which is an interface to the camera and the lens.

Fig. 10 shows an electric circuit built in  
 the camera of the present embodiment, and the like  
 elements to those of Fig. 9 are designated by the like  
 15 numerals.

Connected to a central processing unit (CPU)  
 100 of a microcomputer built in the camera body are  
 a visual axis detection circuit 101, a photometer  
 circuit 102, an automatic focal point detection circuit  
 20 103, a signal input circuit 104, an LCD drive circuit  
 105, an LED drive circuit 106, an IRED drive circuit  
 107, a shutter control circuit 108, and a motor control  
 circuit 109. Signals are exchanged with the focus  
 drive circuit 70 and the aperture drive circuit 111  
 25 arranged in the photographing lens through the mount  
 contact point 67 shown in Fig. 9.

An EEPROM 100a associated with the CPU 100

1 has a visual axis correction data memory function for  
correcting a individual differential error of the visual  
axis.

As described above, the visual axis detection  
5 circuit 101 A/D-converts the output of the eyeball  
image from the image sensor (CCD-EYE) based on the  
difference between the output in the illuminated state  
and the output in the non-illuminated state and sends  
the image information to the CPU 100, which samples  
10 each of characteristic points of the eyeball image  
necessary for the detection of the visual axis in  
accordance with a predetermined algorithm and calculates  
the visual axis of the photographer based on the  
positions of the characteristic points.

15 The photometer circuit 102 amplifies the output  
from the photomentering sensor 40, logarithmically  
compresses it, A/D-converts it, and sends the output  
to the CPU 100 as the luminescence information of each  
sensor. In the present embodiment, the photomentering  
20 circuit 40 has photo-diodes including SPC-L, SPC-C,  
SPC-R and SPC-A for photomentering four areas.

The line sensor 36 of Fig. 10 is a well-known  
CCD line sensor including five line sensors CCD-L2,  
CCD-L1, CCD-C, CCD-R1 and CCD-R2 corresponding to the  
25 five metering points in the image.

The automatic focus detection circuit (focal  
point detection circuit) 103 A/D-converts the voltage

1 obtained from the line sensor 36f and sends it to the  
 CPU 100. SW-1 denotes a switch which is turned on  
 by a first stroke of a release button to start the  
 photometering, the auto-focusing and the detection  
 5 of the visual axis, SW-2 denotes a release switch which  
 is turned on by a second stroke of the release button,  
 SW-AEL denotes an AE lock switch which is turned on  
 by depressing an AE lock button, and SW-DIAL1 and  
 SW-DIAL2 denote dial switches provided in an electronic  
 10 dial (not shown) which are connected to an up/down  
 counter of the signal input circuit 104 to count on  
 rotation clicks of the electronic dial.

Numeral 105 denotes a well-known LCD drive  
 circuit for driving the liquid crystal display element  
 15 LCD. It can display the aperture value, the shutter  
 speed and the preset photographing mode on the monitor  
 LCD 72 and the LCD 54 in the finder simultaneously  
 in accordance with the signal from the CPU 100. The  
 LED drive circuit 106 turns on and off the illumination  
 20 LED (F-LED) 55 and the superimposing LED 51. The IRED  
 drive circuit 107 selectively turns on the infrared  
 ray emitting diodes (IRED1-6) according to surrounding  
 states.

The shutter control circuit 108 controls a  
 25 magnet MG-1, which, when actuated, drives a leading  
 curtain, and a magnet MG-2 which drives a trailing  
 curtain, to impart a predetermined amount of light

1 exposure to a photosensitive member. The motor control  
circuit 109 controls a motor M1 which winds up and  
rewinds a film, and a motor M2 which charges the main  
mirror 32 and the shutter 34. The shutter control  
5 circuit 108 and the motor control circuit 109 carry  
out a series of camera release sequence.

In detecting the visual axis, the eyeball of  
the subject is illuminated by the light beam from the  
illumination means 43, the eyeball image is formed  
10 on the accumulation type image pickup means 44 based  
on the reflected light from the eyeball, the image  
signal from the image pickup means is stored in the  
memory means 21 (RAM) (Fig. 1), and the visual axis  
of the subject is calculated by using the image signal  
15 stored in the memory means. The image pickup means  
has first and second accumulation periods, the memory  
means stores the image signal of the eyeball image  
generated in one of the two accumulation periods, and  
the illumination means emits light in only one of the  
20 two accumulation periods. A difference signal between  
the image signal from the image pickup means generated  
in the first accumulation period and the image signal  
generated in the second accumulation period is  
determined by the differential signal generation means  
25 and the line of vision of the subject is detected by  
using the signal from the differential signal generation  
means. The high luminescence LED 51 illuminates the

- 1 point based on the calculated visual axis information  
and the focus is detected by the focal point detection  
circuit 103 for the object area corresponding to the  
illumination point and the photographing lens 31 is  
5 driven by the focal point adjusting circuit 70.

In accordance with the present invention, when  
the eyeball image is to be detected by using the  
accumulation type image pickup means, the affect by  
the noise due to the external rays is reduced by  
10 properly installing the accumulation method of the  
eyeball image (image information) by the image pickup  
means and the processing method of the image information  
based on the eyeball image from the image pickup means  
so that the visual axis detection apparatus which can  
15 accurately detect the visual axis of the eyeball of  
the photographer (the examined person) who views the  
finder.

1 WHAT IS CLAIMED IS:

1. A visual axis detection apparatus:

conversion means for converting a light from  
an eye of an examined person to an electrical signal;

5 illumination means for illuminating said  
eye;

signal generation means for generating a  
signal relating to a difference between a first signal  
of said conversion means when illuminated by said  
10 illumination means and a second signal of said conver-  
sion means in the absence of illumination; and

detection means for detecting a visual axis  
on the basis of the signal of said signal generation  
means.

15

2. A visual axis detection apparatus according  
to Claim 1 wherein said illumination means includes  
memory means for storing the electrical signal of said  
conversion means in the state where the eye is illumi-  
20 nated by said illumination means, and said signal  
generation means outputs a signal from which is subtracted  
an electrical signal of said conversion means in the  
absence of illumination from the signal stored by said  
memory means.

25

3. A visual axis detection apparatus according  
to Claim 1 wherein said conversion means includes a frame  
transfer-type solid state image pickup means having a

1 first memory and a second memory, said first memory  
stores the electrical signal of said conversion means  
in the state where the eye is illuminated by said  
illumination means, and said second memory stores the  
5 electrical signal of said conversion means in the  
absence of illumination.

4. A visual axis detection apparatus comprising:  
illumination means for illuminating an eyeball  
10 of an examined person;  
image pickup means for accumulating a light  
from the eyeball in a first period and a second period  
as electrical signals;  
control means for making said illumination  
15 means illuminate the eyeball for one of said first  
and second periods to generate a differential signal  
between an electrical signal of said image pickup means  
in said one period and an electrical signal of said  
image pickup means in the other period; and  
20 detection means for detecting a visual axis  
on the basis of said differential signal.

5. Visual axis detection apparatus comprising means for  
illuminating a person's eyeball, and means for generating  
25 a signal representing the visual axis of the eyeball and utilising  
a differential signal generated by light reflected from the eyeball  
when illuminated by said illuminating means but compensated for by  
a measurement of light reflected from the eyeball when not illuminated  
by said illumination means.



6. Visual axis detection apparatus  
substantially as hereinbefore described with reference  
to and as shown in any one of Figures 1 to 4 of the  
accompanying drawings.

Relevant Technical Fields

(i) UK Cl (Ed.M) H4D (DLAT, DLAU, DLAC, DLAD, DLAE, DLAP, DLAX, DLSX, DLPC, DLPG, DLPX, DLAA, DLAB); G1A (AEE, AEN, AEX)

(ii) Int Cl (Ed.5) A61B 3/113

Search Examiner  
DR E P PLUMMER

Date of completion of Search  
5 JANUARY 1994

Databases (see below)

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-  
1-6

Categories of documents

- |  |  |
|--|--|
| X: Document indicating lack of novelty or of inventive step.   | P: Document published on or after the declared priority date but before the filing date of the present application.        |
| Y: Document indicating lack of inventive step if combined with one or more other documents of the same category. | E: Patent document published on or after, but with priority date earlier than, the filing date of the present application. |
| A: Document indicating technological background and/or state of the art.   | &: Member of the same patent family; corresponding document.   |

Category	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2125651 A (KODAK) eg. Abstract	1-6
Y	GB 2125649 A (KODAK) eg. Abstract	1-6
Y	GB 1265878 (PAILLARD SA) Whole document	1, 4, 5
Y	US 5036347 (CANON) Whole document	1-6
X,Y	US 4387974 (USA) eg. Column 5 lines 1-15, 57-65	1, 4, 5 2, 3, 6